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Lizhen Han

Peking University <https://orcid.org/0000-0003-2246-2591>

Maosun Fu

Shandong University

Yihua Liu

Shandong University

Jinzhu Jia (✉ jzjia@math.pku.edu.cn)

<https://orcid.org/0000-0002-6554-2463>

Lu Wang

Physical Examination Office of Shandong Province

Research article

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Posted Date: July 27th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-15547/v2>

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Spatial Differences of Overweight and Obesity among Schoolchildren in Shandong Province, China

Lizhen Han, Ph.D,¹ Maosun Fu, A. Prof.,² Yihua Liu, MPH,² Jinzhu Jia, Ph.D^{1,*} and Lu Wang, Ph.D^{3,*}

¹ Department of Biostatistics, School of Public Health, Peking University, Beijing, China, No. 38, Xueyuan Road, Haidian District, Beijing City, 100191, China

² Department of Social Medicine and Maternal & Child Health, School of Public Health, Shandong University, Jinan 250012, China

³ Physical Examination Office of Shandong Province, Jinan 250014, China

* Correspondence: jzzjia@math.pku.edu.cn

Correspondence

Jinzhu Jia, Ph.D, Department of Biostatistics, School of Public Health, Peking University, Beijing, China, No. 38, Xueyuan Road, Haidian District, Beijing City, 100191, China; Email: jzzjia@math.pku.edu.cn; Tel: +86-1580-104-9187

Lu Wang, Ph.D, Physical Examination Office of Shandong Province, Jinan, China, No.9 Yandong New Road, Lixia District, Jinan City, Shandong Province, 250014, China; Email: luwang2716@163.com; Tel: +86-1867-885-9267

Abstract

Background: Overweight and obesity are becoming a big issue in Shandong province. Based on the big data of children and adolescents in Shandong province, we try to explore the spatial differences and explain the causes of this phenomenon, so as to provide suggestions and data support for solving related problems in similar areas.

Methods: The sample came from Shandong province's physical examination data in 2017. A total of 10.27 million schoolchildren aged 6-18 years were included. ArcGIS software (hot spot analysis) was used to explore the spatial differences, and regional influencing factors were analyzed by multinomial logistic regression.

Results: The prevalence of overweight and obesity among schoolchildren aged 6-18 years were 17.93% and 6.79%, respectively. Moreover, boys/girls, urban/rural areas both showed that the former rate was higher than the latter, and the 9-11 age group was confirmed to have the highest prevalence. Regional distribution illustrated that, in Shandong province, the areas with high prevalence of overweight and obesity

were mainly concentrated in the central, northern and eastern parts, and the hot spot clusters were located in Yantai and Weihai, while the low-value areas were aggregated in the western (boys) and southern (girls) regions. Further exploration revealed that total retail sales of consumer goods (CGTRS) and per capita disposable income (PCDI) were confirmed as risk factors for regional obesity level.

Conclusions: The spatial difference of overweight and obesity is statistically significant between the eastern region (high value cluster) and the western region (low value cluster), and it is influenced by some regional factors, suggesting that for a few regions, relevant department should pay more attention to this phenomenon. More education on this problem should be done to make people know more about health, and more researches should be done to see what intervention could solve this problem.

Keywords: body mass index, overweight and obesity, spatial differences, Shandong province, schoolchildren

Background

As an important stage in the process of growth, childhood and adolescence not only cover the growth and development of children's body organs and systems (including general type, lymphatic system type, etc.), but also involve many significant nodes (such as growth spurt, sexual development, psychological development, etc.) for transition to adulthood. Meanwhile, children's growth and development as a mirror of national and social development, to a certain extent, reflects the development situation of a country in economic, education, medical and other aspects. In this condition, as a public health problem [1], the issue of overweight and obesity among schoolchildren cannot be ignored.

The prevalence of overweight and obesity among school-age population has shown an obvious upward trend year by year in the world. According to the report from WHO, it demonstrated that between 1975 and 2016, the rate of overweight and obesity among children and adolescents aged 5-19 has risen dramatically from just 4% to just over 18% [2]. Likewise, similar findings have been confirmed in the national student physical and health survey data: the rate of overweight and obesity among students aged 7-18 showed a continuous growth trend from 1985 to 2014 in China, and the total prevalence of overweight and obesity reached 19.4% in 2014 [3]. The Report

on Childhood Obesity in China pointed out that if we do not adopt effective intervention measures, the prevalence of overweight and obesity among schoolchildren aged 7-18 years in China will reach 28.0% in 2030 [4].

Worldwide, about 3.4 million deaths, 3.9% loss of life and 3.8% disability adjusted life years (DALYs) are associated with overweight and obesity [5]. Researches illustrated that childhood obesity not merely causes recent target organ damage [6], such as left ventricular hypertrophy, carotid intima media thickness increased, but also increases the risk of chronic diseases like obesity, hypertension, coronary heart disease and type 2 diabetes in adulthood [7]. A recent study in Germany [8], for instance, showed that compared with men who were never overweight in childhood, men who were overweight at the age of 7 and 13 but normalized in their early adulthood were at higher risk for type 2 diabetes, while the risk is lower than that of men who have been overweight. In addition, the maximum inspiratory pressure of children with overweight and obesity is relatively lower than that of children with normal development and nutrition [9]. However, adipose tissue needs more oxygen during metabolism, which will further increase the lung burden of children with overweight and obesity [10]. It is worth noting that excessive fat will also have adverse effects on T cells, reducing the body's ability to prevent and combat cancer [11]. In middle age, cognitive function will be affected and reduced [12]. Therefore, it is necessary to strengthen surveillance and intervention of overweight and obesity in childhood and adolescence, and it will help to reduce the risk of chronic disease and cognitive decline in adulthood.

Economic and environmental factors also have many impacts on overweight and obesity. Overweight and obesity levels in economically developed regions are more serious and growing faster than those in less developed regions (developing countries) [13,14]. With the popularity of otaku culture in recent years and the rise of live broadcast (e.g. “eating broadcasting”), sedentary lifestyle is becoming more and more common, which greatly reduces energy consumption and increases the opportunity to eat [15]. Moreover, the reduction of sports activities

[16,17] makes energy consumption and intake unable to reach a balance, further aggravating the occurrence of overweight and obesity in children. In addition, environmental factors such as air pollution also have negative impacts on such problems. People exposed to higher concentrations of ultrafine particles, nitrogen dioxide (NO_2), $\text{PM}_{2.5}$ or elemental carbon have a higher risk of overweight and obesity [18]. However, there were few articles focusing on the effect of regional factors on the spatial differences.

As a populous province in China, Shandong province has the second largest population (100.06 million people). Moreover, the total prevalence of overweight and obesity among children in Shandong province exceeds the national average (25.95% vs. 19.40%) [3,19]. At present, many scholars have analyzed the children or adolescents with overweight and obesity in Shandong province from multiple perspectives (e.g., influencing factors, prevalence) [20-22], but in contrast, there is few research which has focused on spatial differences. In-depth analysis from the spatial perspective can help us to identify the distribution of diseases more accurately, making people know well on which part of the people have more severe problems. Meanwhile, combined with local factors, it is more helpful to discover the potential reasons for the differences. Shandong province has a peninsula located between the Yellow Sea and the Bohai Sea, and also has a range of inland areas. The local environment is quite different, and the level of economic development is extremely unbalanced, especially between the eastern and western regions (e.g., the total gross domestic product (GDP) of Qingdao, Weihai and Yantai in the east in 2017 was 2.44 times higher than that of Liaocheng, Heze and Dezhou in the west) [23]. Studies have confirmed that the growth of schoolchildren's obesity is closely related to the regional economy (the growth rate in economically developed areas is faster than that in underdeveloped areas) [13]. Due to these phenomena, Shandong province has a high research value and representation in the problem of overweight and obesity among schoolchildren in China. As a result, this article used the Shandong province's physical examination

data (2017) to analyze the spatial differences of overweight and obesity among schoolchildren aged 6-18, aiming to discover the regional differences and related influencing factors, and provide some suggestions to help relevant departments to further improve relevant policies and measures according to the characteristics of each area.

Methods

Data Source

The sample came from physical examination data of students from September to December 2017 in Shandong province. After adjusting for gender and age, the missing data and extreme values (275,449) were deleted (screening range: $-3 < \text{BMI } z \text{ score} < 3$). A total of 10,265,861 schoolchildren aged 6-18 years were included, covering all primary, junior and senior high schools (the age brackets are 6-12,13-15 and 16-18, respectively) in all 17 cities (137 counties) in Shandong province. All of them have the complete information, such as district, gender, age, height, weight etc. Among them, there were 5,521,618 boys, accounting for 53.79%.

Measurement Methods

According to the *Measures for the administration of health examination of primary and middle school students*[24] issued by the National Health Commission of the People's Republic of China and the Ministry of Education of the People's Republic of China and the relevant provisions of the *Measures for the implementation of health examination management for primary and middle school students in Shandong province*[25] issued by the Shandong Provincial Education Department, the state stipulates that students will receive regular health examination every school year. Before implementation, it will be organized by the health administrative department at or above the county level, and will conduct strict training for all medical staffs who participated in physical examination (from 1373 medical institutions in Shandong province). In addition, through the schools' teachers, they will inform the students and their parents of the relevant details of the physical examination and

seek their consent. After the physical examination, the results will be reported to the students and their parents in the form of a report.

All physical examinations were measured using a uniform protocol and tools, and all data related to this study were measured by basic physical measurement methods, without involving laboratory examinations. Before the examination, the measurement tools were calibrated according to the *Health examination methods for primary and secondary schools in Shandong province*. During the measurement, all students were required to take off their hats and shoes, and to wear light clothes. The height was measured using a human height gauge, accurate to 0.01 cm. The weight measurement used a lever scale or a portable electronic weight measurement instrument, accurate to 0.01 kg. The original data is from Shandong province's physical examination data (2017). Medical staffs took the measures. We extracted all the data with these two indexes from the database and calculated the body mass index (BMI, BMI=body weight (Kg) / height² (m²)) of each individual. BMI z scores were calculated simultaneously and used to screen outliers (screening range: -3 < z < 3) [26].

Judging Criteria for Overweight and Obesity

According to the *Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity* formulated by Cole and others in 2012 [27], the BMI of all samples was compared with the corresponding threshold points of each age (subdivided into half-year) to identify individuals suffering from overweight and obesity.

Explanatory Variables

Based on which factors related to obesity of children and adolescents [28,29], the explanatory variables of economy and education were selected from the provincial public statistical yearbooks. After collinearity examination, nine variables were finally included, namely gross domestic product (GDP), total retail sales of consumer goods (CGTRS)—sales amount of physical commodities for non-production and non-business purposes

(including catering services), per capita disposable income (PCDI), general public budget expenditure (GPBE)—state financial expenditures that are spent on public services, education, medical care and social security, etc., number of full-time teachers (FTT)—weighted by the number of students in the region, representing the number of teachers per thousand students, proportion of boys (BP) and the proportion of different age groups (AP)—the age group was divided into 4 segments, which are 6-8, 9-11, 12-14 and 15-18 years respectively, and the first three segments were used as explanatory variables. In this study, the age was recorded for half a year and calculated according to the difference between the physical examination date and their birthday. "6 months" was taken as the limit, and those who were not satisfied with this limit were recorded as "whole year old". For those over 6 months but less than 12 months, half a year will be added for recording. In order to better correspond to other contents in this paper, the multinomial analysis was mainly classified according to the boundary point defined by natural breaks (Jenks) method which directly reported from the ArcGIS software (see the spatial analysis section for the principle of this method). Because there were few regions in the fifth level (only 8.80% in obese areas), level 4 and level 5 were merged in this part, and the degree of regional overweight (or obesity) was determined as 4 grades (1-4) from low to High.

Statistical Analysis

Raw data was extracted through SQL Sever2017, and SPSS 22.0 was used to analyze the data. The measurement data were described by the mean \pm standard deviation, t-tests and the analysis of variance (ANOVA) were used for comparison between groups. The counting data was expressed by the rate (%), and the comparison between groups was tested by chi-square tests. Furthermore, multinomial logistic regression analysis was used to analyze the risks and correlations among the above-mentioned influencing factors related to overweight and obesity from the overall level of the region. A probability level of $p < 0.05$ was used to indicate statistical significance.

Spatial Analysis

This study used ArcGIS 10.2 software to analyze spatial distribution, regional differences, etc. Among them, its method of natural breaks (Jenks) [30] was utilized to clarify the distribution difference of overweight and obesity rates in the area. This is a data classification method, which aims to determine the best arrangement of values in different categories. This is achieved by seeking to minimize the average deviation of each class from the class mean and maximize the deviation of each class from the average of other groups. Besides, in order to find out whether there is spatial clustering in the Shandong province, spatial autocorrelation (Global Moran's I) and hot spot analysis (Getis-Ord Gi*) were applied to this study.

Spatial autocorrelation (Global Moran's I) is a method for measuring spatial autocorrelation based on element locations and element values. Given a set of features and an associated attribute, it evaluates whether the pattern expressed is clustered, dispersed, or random. This method evaluates the significance of data results by calculating the Moran's I index value, z-score and p-value. If the values (Moran's I index) in the dataset tend to cluster spatially (high values cluster near other high values, low values cluster near other low values), the Moran's index will be positive. On the contrary, it will be negative. If positive cross-product values balance negative cross-product values, the index will be near zero [31].

The hot spot analysis calculates the Getis-Ord Gi* statistic for each feature in a dataset. Through the resultant z-scores and p-values, the position where the high-value or low-value elements cluster in space can be illustrated. After comparing local features with all features, if the local sum is statistically different from the expected sum (not randomly generated), a statistically significant z-score will be resulted.

The Getis-Ord local statistic is given as:

$$G_i^* = \frac{\sum_{j=1}^n w_{i,j}x_j - \bar{X} \sum_{j=1}^n w_{i,j}}{S \sqrt{\left[n \sum_{j=1}^n w_{i,j}^2 - (\sum_{j=1}^n w_{i,j})^2 \right] / (n-1)}} \quad (1)$$

Where x_j is the attribute value for feature j , $w_{i,j}$ is the spatial weight between feature i and j , and:

$$\bar{X} = \frac{\sum_{j=1}^n x_j}{n} \quad (2)$$

$$S = \sqrt{\frac{\sum_{j=1}^n x_j^2}{n} - (\bar{X})^2} \quad (3)$$

The G_i^* statistic returned for each feature in the dataset is the z-score. For statistically significant positive z-scores, the larger the z-score is, the more intense the clustering of high values (hot spot). On the contrary, it shows clustering degree of low values (cold spot) [32].

Results

Basic characteristics of research subjects

The sample was derived from the physical examination data of primary and high school students in Shandong province (2017). Among them, 6-18 year old students from 17 cities in Shandong province were selected as subjects, including 10,265,861 schoolchildren aged 6-18, among whom 53.79% were boys. The average age was 10.62 ± 2.88 years. There was a strong positive association between BMI and the proportion of urban children ($r=0.863, p < 0.001$). In addition, there was a statistically significant difference in BMI between students aged 6-18 years in different cities ($F = 3.119, p < 0.001$). Among them, the BMI of Yantai and Weihai were higher among the four age groups (half-year-old was included in the whole-year-old), while the value of Weifang, Heze and Binzhou ranked at the bottom. The results were shown in Table 1.

Table 1 Basic characteristics of schoolchildren aged 6-18 in different cities of Shandong province

in 2017

City	Sample	Boys	Urban	Age	Age-specific BMI(kg/m ²)			
	size	(%)	(%)	(year)	6-8	9-11	12-14	15-18

Binzhou	354099	52.54	31.73	10.48±2.72	16.38±2.50	18.37±3.41	20.05±3.56	20.84±3.41
Dezhou	577370	52.59	36.28	10.51±2.75	16.67±2.46	18.47±3.35	20.15±3.44	21.11±3.26
Dongying	215036	51.50	56.97	11.20±3.10	16.81±2.74	18.87±3.72	20.58±3.83	21.53±3.44
Heze	1237352	57.03	23.75	10.10±2.49	16.71±2.40	18.41±3.23	19.98±3.38	20.65±3.27
Jinan	648548	52.24	59.57	10.79±3.11	16.85±2.67	18.99±3.68	20.66±3.82	21.57±3.53
Jining	915782	55.47	33.92	10.45±2.71	16.61±2.60	18.49±3.44	20.23±3.65	21.21±3.50
Laiwu	105503	52.00	47.87	11.06±2.95	16.70±2.54	18.68±3.56	20.61±3.82	21.71±3.59
Liaocheng	710080	55.68	28.98	10.01±2.48	16.67±2.38	18.42±3.28	20.13±3.42	20.86±3.31
Linyi	1327915	54.03	33.48	10.29±2.76	16.67±2.56	18.44±3.45	20.24±3.62	21.12±3.40
Qingdao	837356	52.12	52.46	10.84±3.01	16.65±2.64	18.67±3.59	20.42±3.80	21.33±3.48
Rizhao	281874	53.37	41.42	10.58±2.76	16.61±2.43	18.31±3.28	20.14±3.46	21.22±3.36
Taian	528837	52.07	36.77	11.07±3.07	16.75±2.62	18.75±3.57	20.60±3.73	21.44±3.49
Weihai	204411	51.48	60.20	10.79±3.00	16.88±2.74	18.98±3.74	20.87±3.96	21.57±3.63
Weifang	878920	52.85	42.65	11.03±2.95	16.38±2.57	18.32±3.51	19.88±3.63	20.83±3.34
Yantai	520237	51.47	55.37	11.39±3.20	16.90±2.78	18.99±3.76	20.81±3.95	21.65±3.56
Zaozhuang	488356	56.79	47.79	10.53±2.90	16.85±2.47	18.63±3.35	20.32±3.57	20.84±3.42
Zibo	434185	51.61	50.27	11.52±3.25	16.80±2.70	18.90±3.70	20.70±3.85	21.11±3.48

Basic information of overweight and obesity

In 2017, the overall overweight rate of school-age population in Shandong province was 17.93%, and the difference in overweight rate among cities was statistically significant ($\chi^2=9253.18, p < 0.001$). Between different genders, the overall overweight detection rate of boys was higher than that of girls (19.72% vs. 15.84%, $\chi^2=$

26070.31, $p < 0.001$), and the former was higher than the latter between urban and rural areas (19.77% vs. 16.69%, $\chi^2 = 15925.82, p < 0.001$). Likewise, the same results were detected in every city in Shandong province. The results were shown in Additional file 1. Moreover, this study found that the prevalence among different age groups showed a trend of gradual decline after an early rise. Except Dongying and Zibo ($p = 0.580$ and 0.132 , respectively), Linear-by-Linear associations were detected in other cities.

Obesity rates also have statistically significant differences among cities ($\chi^2 = 16632.12, p < 0.001$). However, the obesity rate was much lower than the overweight rate, and the overall prevalence was only 6.79% in 2017. Without doubt, the same numerical differences as overweight have been obtained in both gender (boys/girls: 9.47%/3.67%, $\chi^2 = 135455.04, p < 0.001$) and district (urban/rural: 7.86%/6.07%, $\chi^2 = 12469.84, p < 0.001$). Linear-by-Linear associations with the similar trend as overweight were detected in 16 cities (except Rizhao). The results were shown in Additional file 2.

Spatial Analysis Results

The spatial analysis of overweight and obesity among schoolchildren in Shandong province in 2017 showed that the areas with higher rates were mainly concentrated in the eastern Shandong peninsula, central and northern regions. Overall, the geographical distribution of overweight and obesity in the province was roughly similar. Furthermore, the entire difference of overweight and obesity rates in different regions (137 counties) were statistically significant ($\chi^2 = 27723.56, p < 0.001$, $\chi^2 = 34574.91, p < 0.001$). Whether overweight or obesity, from the perspective of the city, Weihai was the city with the highest prevalence. The results were shown in Figure 1 and Figure 2.

Focusing on the overweight regional differences between different genders, it was found that the distributions of male and female students in the main high-prevalence areas were similar to the overall situation.

Nevertheless, there were also new high-prevalence areas scattered in other regions. Even so, the prevalence in the eastern part of the peninsula was still the highest. On the other hand, compared with the former, gender differences in obesity showed characteristics that were more consistent with the general situation. The results were shown in Figure 3-6.

Further, this study analyzed whether there was spatial aggregation through spatial autocorrelation, and concluded that there was obvious spatial aggregation in all classifications. The results were shown in Table 2.

Table 2 Spatial autocorrelation of overweight and obesity among schoolchildren in Shandong

province in 2017

Variety	Regional overweight rate			Regional obesity rate		
	Moran's I	z	p	Moran's I	z	p
Total	0.33	5.94	<0.001	0.46	8.08	<0.001
Boys	0.39	6.97	<0.001	0.53	9.24	<0.001
Girls	0.29	5.14	<0.001	0.35	6.17	<0.001

Combined with hot spot analysis and research, it was found that in terms of overweight, the high-value concentration areas in Shandong province were mainly aggregated in Weihai, Yantai and Qingdao. The overall cold-spot districts were relatively concentrated in the northwest of Shandong and a few areas in Linyi and Weifang. It is worth noting that although the distribution between genders was similar in hot spots, there were large differences in low-value areas—boys were mainly distributed in the western region, while girls were mostly concentrated in the southeast area. The results were shown in Figure 7-9.

In response to the obesity issue, the main manifestation was that the high-value aggregation range in the eastern part of Shandong peninsula was enlarged and the aggregation was intensified, while the low-value

aggregation range was more inclined to the southern distribution (the overall, male and female results were the same). In addition, the distribution difference of cold spot was still obvious between the sexes (boys: southwest region, girls: southeast area). The results were shown in Figure 10-12.

Influencing factors Analysis

After the collinearity diagnostics, nine kinds of influencing factors (including 137 counties in the province): gross domestic product (GDP), total retail sales of consumer goods (CGTRS), per capita disposable income (PCDI), general public budget expenditure (GPBE) and number of full-time teachers (FTT) were included in the multinomial logistic regression model. Moreover, the units of these variables were 100 million yuan, 10 million yuan, 100 yuan, 10 million yuan, 1 person and 100 person per square kilometer, respectively. In addition, the proportion of boys (BP) and the proportion of different age groups (AP) were also included in the analysis as covariates.

According to the regional classification in the previous results (ArcGIS part), the comprehensive analysis of factors and regional overweight (or obesity) levels demonstrated that the CGTRS and PCDI were the risk factors in the counties with higher degree (level 4) of overweight and obesity compared with the lowest level (level 1) counties. Nevertheless, GDP, FTT, BP and AP showed no statistically significant effect on the degree of overweight and obesity in different regions. GPBE showed a protective effect in the regional obesity level 4. The results were shown in Table 3-4.

Table 3 Association between regional influencing factors and overweight of schoolchildren in

Shandong province in 2017

Factors	β	S.E.	Wald	p	$Exp(\beta)$	95%CI for $exp(\beta)$
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						Lower	Upper
						bound	bound
overweig-							
ht level							
2	Intercept	13.174	13.035	1.021	0.312		
	GDP	-0.003	0.002	1.609	0.205	0.997	0.993
	CGTRS	0.007	0.008	0.782	0.376	1.007	0.992
	PCDI	-0.007	0.011	0.484	0.487	0.993	0.972
	GPBE	-0.003	0.032	0.008	0.927	0.997	0.936
	FTT	-0.012	0.020	0.334	0.563	0.988	0.950
	BP	-0.218	0.261	0.697	0.404	0.804	0.483
	AP ₆₋₈	0.070	0.092	0.577	0.447	1.073	0.895
	AP ₉₋₁₁	0.011	0.113	0.010	0.920	1.011	0.811
	AP ₁₂₋₁₄	-0.014	0.098	0.020	0.888	0.986	0.814
3	Intercept	-4.037	13.172	0.094	0.759		
	GDP	-0.003	0.002	2.410	0.121	0.997	0.993
	CGTRS	0.013	0.007	3.208	0.073	1.013	0.999
	PCDI	0.013	0.010	1.649	0.199	1.013	0.993
	GPBE	-0.013	0.031	0.170	0.680	0.987	0.930
	FTT	0.018	0.019	0.873	0.350	1.018	0.980
	BP	-0.009	0.264	0.001	0.972	0.991	0.590
	AP ₆₋₈	0.123	0.092	1.779	0.182	1.130	0.944
							1.354

	AP ₉₋₁₁	-0.051	0.114	0.198	0.656	0.950	0.760	1.189
	AP ₁₂₋₁₄	-0.058	0.099	0.342	0.559	0.944	0.778	1.145
4	Intercept	-0.811	15.793	0.003	0.959			
	GDP	-0.001	0.002	0.147	0.701	0.999	0.995	1.003
	CGTRS	0.018	0.007	6.135	0.013	1.019	1.004	1.034
	PCDI	0.024	0.010	5.070	0.024	1.024	1.003	1.045
	GPBE	-0.055	0.035	2.533	0.111	0.946	0.884	1.013
	FTT	0.023	0.021	1.181	0.277	1.023	0.982	1.066
	BP	-0.100	0.311	0.104	0.747	0.905	0.492	1.664
	AP ₆₋₈	0.048	0.103	0.222	0.637	1.050	0.858	1.284
	AP ₉₋₁₁	0.018	0.129	0.018	0.892	1.018	0.790	1.311
	AP ₁₂₋₁₄	-0.142	0.115	1.524	0.217	0.867	0.692	1.087

Table 4 Association between regional influencing factors and obesity of schoolchildren in Shandong province in 2017

Regional		95%CI for $\exp(\beta)$						
obesity	Factors	β	S.E.	Wald	p	$\exp(\beta)$	Lower bound	Upper bound
level								
2	Intercept	10.808	11.891	0.826	0.363			
	GDP	0.001	0.002	0.069	0.793	1.001	0.997	1.004
	CGTRS	-0.002	0.007	0.056	0.813	0.998	0.984	1.013
	PCDI	0.000	0.011	0.000	0.984	1.000	0.978	1.022

	GPBE	0.007	0.027	0.075	0.784	1.007	0.956	1.061
	FTT	-0.012	0.020	0.351	0.553	0.988	0.949	1.028
	BP	-0.115	0.231	0.249	0.618	0.891	0.567	1.401
	AP ₆₋₈	-0.069	0.086	0.640	0.424	0.934	0.789	1.105
	AP ₉₋₁₁	0.028	0.103	0.075	0.785	1.028	0.841	1.258
	AP ₁₂₋₁₄	-0.073	0.096	0.576	0.448	0.930	0.770	1.122
3	Intercept	-12.110	11.825	1.049	0.306			
	GDP	-0.001	0.002	0.115	0.735	0.999	0.996	1.003
	CGTRS	0.005	0.007	0.591	0.442	1.005	0.992	1.019
	PCDI	0.021	0.011	3.849	0.050	1.021	1.000	1.043
	GPBE	-0.003	0.024	0.021	0.886	0.997	0.951	1.044
	FTT	0.007	0.019	0.144	0.705	1.007	0.970	1.046
	BP	0.144	0.233	0.381	0.537	1.155	0.731	1.822
	AP ₆₋₈	0.080	0.084	0.905	0.342	1.083	0.919	1.276
	AP ₉₋₁₁	-0.083	0.106	0.622	0.430	0.920	0.748	1.132
	AP ₁₂₋₁₄	-0.019	0.097	0.037	0.848	0.982	0.812	1.186
4	Intercept	27.628	20.835	1.758	0.185			
	GDP	-0.003	0.003	0.946	0.331	0.997	0.992	1.003
	CGTRS	0.019	0.008	5.837	0.016	1.020	1.004	1.036
	PCDI	0.046	0.013	12.653	0.000	1.047	1.021	1.074
	GPBE	-0.075	0.033	5.276	0.022	0.928	0.870	0.989

FTT	0.018	0.022	0.698	0.404	1.019	0.976	1.064
BP	-0.694	0.436	2.535	0.111	0.500	0.213	1.174
AP ₆₋₈	0.029	0.116	0.061	0.804	1.029	0.820	1.292
AP ₉₋₁₁	-0.074	0.164	0.204	0.652	0.928	0.673	1.282
AP ₁₂₋₁₄	-0.085	0.127	0.451	0.502	0.918	0.716	1.178

Discussion

In recent years, with the rise of the carry-outs industry, the dietary patterns and lifestyle have changed to a great extent. Moreover, this kind of catering mode has given birth to many unhealthy lifestyles (such as ‘otaku’, irregular diet, sedentary life, etc.). Under the joint influence of various factors, the problem of overweight and obesity among school-age children and adolescents has become increasingly prominent, and the prevalence has also shown an increasing trend [3,21]. This study proved the spatial distribution and aggregation of overweight and obesity among schoolchildren aged 6-18 in Shandong province, and combined with the factors of various regions, confirmed the influence of economy on this problem.

Among the regions covered by the study, Yantai and Weihai have higher BMI in any age group, while the value of Weifang, Heze and Binzhou ranked at the bottom. Combined with the analysis of its correlation with the proportion of urban children, the formation of this difference may be more influenced by the degree of urbanization [33]. In addition, compared with the flat trend of BMI in high-income English-speaking countries, the accelerated growth trend in China was obvious [34,35], and all cities should be more alert to BMI. Furthermore, the rise of BMI will also bring negative effects to the economy: one BMI point above 30 was associated with a 2% decrease in income, a 3% increase in social transfer payments, and a 4% increase in healthcare costs [36]. This study found that the overweight and obesity rates of Shandong province reached

17.93% and 6.79% in 2017, far higher than the earlier screening results (13.79% and 5.79% respectively) of the same standard in the 5-18 year-old population in China (boys: 53.33%) [27]. Since the implementation of the "Targeted Poverty Alleviation" policy in 2015, people's living standards have been continuously improving. As a result, overweight has become a more accessible physical condition, and the overweight rate has reached the current "high".

The results of prevalence were consistent with other researches in terms of gender, urban and rural areas (boys > girls, urban > rural) [13,37]. The difference between the sexes may be caused by the corporeity that boys are more prone to be obese than girls (e.g. girls are more concerned about body shape) [38], while the distinction between urban and rural areas is more influenced by economic and environmental factors [33]. With the rapid development of social and economic level, albeit the gap between urban and rural areas is continuously narrowing, urban children still have more opportunities to consume large amounts of high-energy foods and have less exercise. Likewise, risk factors such as obesity family history and high smoking rate of mothers were higher than those in rural areas, and protective factors (e.g. breast-feeding rate) were lower [39]. The multifaceted interactions eventually formed this difference. Besides, there is another point that cannot be ignored—from the comparison between urban and rural areas in Additional file 1 and 2, it can be seen that although the overweight and obesity rates in urban areas were higher than that of the country, the gap between the two was not very large (2011/2017: 9.9%/4.5%) [13]. The growth rate in rural areas was faster than that in urban areas. It is suggested that more attention should be paid to the publicity and popularization of health knowledge in rural areas, so as to prevent the generation of "chubby child" in the country.

This study divided the age into 4 age groups. Analysis by age groups showed that the overweight and obesity rates in the 9-11 age group were higher than those in other groups. In general, the detection rate of

childhood (6-11 years old) is higher than that of adolescence (12-18 years old). At the same time, after the age of 9-11, along with the increase of age, a significant decrease in the rate can be seen. This was consistent with the previous research results of other scholars [13]. Peng Jia and others pointed out that the children's overweight and obesity rates will decline with the passage of time. The occurrence of this phenomenon is most likely affected by the physical growth during adolescence (e.g. sudden increase in height), which consumes a lot of nutrition and makes some "pseudo-obese" individuals normal. Consequently, this suggests that parents need not worry too much about children's slight overweight or obesity. As children grow, this situation will naturally be improved. However, intervention against the excessive obese children is still necessary.

Lately, an article similar to this one was published in the journal *BMJ open* [37]. It also used the physical examination data of primary and secondary school students in Shandong province to analyze the spatial distribution of overweight and obesity. Its content, however, is relatively limited. Only the distribution and clustering differences of male/female were studied, and the screening criteria of overweight/obesity individuals were older, which was not conducive to comparative analysis in the future. In view of the above deficiencies, this paper adopted the internal detailed drawing method based on the unit of a large geographical range for the first time, which more intuitively presents the regional aggregation differences within each city. Meanwhile, it is helpful to integrate regional factors more comprehensively, carefully and effectively, and to explore regional differences and their specific causes. In addition, the use of new international standards (IOTF [27]) will help to enhance the reference value of this article.

We found that in 2017, there were statistically significant spatial differences in overweight and obesity among schoolchildren in Shandong province. Among them, the areas with higher prevalence were concentrated in the eastern, central and northern regions, especially in Yantai and Weihai (the economic level ranks high in the

province [23]). Similarly, the high-value aggregation of these two cities has also been confirmed in the hot spot analysis. Although economic factors (such as GDP, etc.) have been proved to have positive association with the regional overweight/obesity level [28], this study has not detected them. The main reason for this may be that GDP covers a wide range, including consumption, investment, government spending and net exports, etc. Its impact on overweight and obesity is easily influenced by other confounders in GDP, and with the inclusion of such factors as CGTRS, which can more specifically reflect the consumption related to obesity, the role of GDP was weakened. If only GDP is used to analyze its relationship with overweight and obesity, it can be detected as a risk factor in regional obesity level 3-4 (e.g., level 4: $p=0.007$, $Exp(\beta)=1.004$ (95% CI: 1.001 - 1.007)). However, the reason for the formation of high-value aggregation is not clear, and further research and discussion are needed. On the other hand, albeit the aggregation area of hot spot between the sexes were distributed in the same way, the results of cold spot clusters differs greatly (boys/girls: western & southwest/ southeast). Southwest and southeast regions, where low values were concentrated, were relatively backward in economic development in the province, and their major economic indicators were obviously lower than those of other cities [23]. Combined with the results of multinomial logistic regression analysis, CGTRS and PCDI have certain "promoting" effects on the development of overweight and obesity, thus forming low-value aggregation in these two regions. However, for the regional difference of low-value clusters between different genders, there are few relevant research data to refer to, and no definite conclusion can be drawn at present. It is initially suspected that this may be related to the difference in unique dietary habits (high intake of grains, milk and fast food was associated with high risk of obesity [40]) and concepts (such as regarding overweight or obesity as beauty) between the two places, and the specific reasons need further in-depth study.

In order to better analyze the specific reasons for internal regional differences in Shandong province, this study used multinomial logistic regression analysis to analyze various regional influencing factors which covering the whole counties. The results illustrated that CGTRS and PCDI were risk factors for both overweight and obesity level in the region. Taking the level 4 (highest level) as an example, compared with those level 1 regions with lower CGTRS and PCDI, the risk of high-value regions developing into the areas with the highest level (level 4) of obesity in Shandong province were 1.020 (95% CI: 1.004 - 1.036) and 1.047 (95% CI: 1.021 - 1.074) times, respectively. Studies have confirmed that the economic status is positively correlated to the occurrence of overweight and obesity among children and adolescents [28,41,42]. Social economy often acts on children through indirect influence on family economy [43]. When residents have more material and financial resources, as the consumption power increases, the threshold for the related needs to be converted into demand will be greatly reduced, and more expenses will be invested in food and use. Meanwhile, as factors that can improve obesity: per capita edible oil [44], the use of washing machines [44], electronic equipment [45] and the per capita disposable income [28], they explained the negative effects of CGTRS and PCDI to a certain extent. However, aiming at the GPBE, it is still impossible to find out the specific reasons for its protective effect, which needs further study.

This study systematically described the spatial differences and influence factors of overweight and obesity among schoolchildren in Shandong province. It had a large sample size, strict on-site quality control and innovative map presentation. Likewise, the result was highly reliable. However, this study also has the following shortcomings: (1) Using BMI as an indicator of overweight and obesity, cannot distinguish between muscle and fat [46,47]. (2) This study has not been able to collect more detailed household, educational and environmental data (such as parents' obesity status, parents' education level, temperature, air pollution, etc.) [18,28,29,48], these proven factors can make the causes of regional differences more effective and comprehensive exploration, so the

analysis of influencing factors needs further improvement. Therefore, considering the feasibility, it is suggested that waistline [49] or skinfold thickness [50] should be added to the future physical examination of students to improve the accuracy of individual screening for overweight and obesity.

Conclusions

In conclusion, there were significant spatial differences in overweight and obesity among schoolchildren aged 6–18 years in Shandong province, especially between the eastern and western areas. The influence of some regional factors on overweight and obesity of schoolchildren has been confirmed. It is suggested that the government health department should pay more attention to the hot spot clusters and try to do more researches on what caused this phenomenon. Here we found the influence of regional economic factors (e.g. CGTRS and PCDI), more research could be done to show if these are causations.

Declarations

Ethics approval and consent to participate

This cross-sectional study was consulted to the ethics committees of Shandong Center for Disease Control and Prevention. Ethics approval was not available in this study because we did not include any data of students' personal information, including name, identity information, address, telephone number, etc. This study only showed the secondary aggregated data on county-level, therefore, waived off ethical approval.

Consent for publication

Not applicable.

Availability of data and materials

Data of the study was not publicly available, the datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research is supported by the Peking University start up fund.

Authors' contributions

LH, MF and YL conceived and designed the study. MF and LW provided the source data of the study. LH and JJ prepared software and performed the statistical analysis. LH prepared the manuscript and interpreted the data. MF, YK, JJ and LW

assisted with the editing of the paper and provided critical comments. JJ and LW revised it critically for important intellectual content. All authors read and approved the final manuscript.

Acknowledgments

The authors would like to express their gratitude for the support from Chengchao ZHOU, the professor of Department of Social Medicine and Maternal & Child Health, School of Public Health, Shandong University, as well as the support received from Prof. Bo XI, another professor of Department of Epidemiology, School of Public Health, Shandong University.

References

1. Williams, E.P.; Mesidor, M.; Winters, K.; Dubbert, P.M.; Wyatt, S.B. Overweight and obesity: prevalence, consequences, and causes of a growing public health problem. *Curr Obes Rep* **2015**, *4*, 363-370, doi:10.1007/s13679-015-0169-4.
2. WHO. Obesity and overweight. Available online: <http://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight> (accessed on 29 August).
3. Wang, S.; Dong, Y.H.; Wang, Z.H.; Zou, Z.Y.; Ma, J. Trends in overweight and obesity among Chinese children of 7-18 years old during 1985-2014. *Chinese Journal of Preventive Medicine* **2017**, *51*, 300-305, doi:10.3760/cma.j.issn.0253-9624.2017.04.005.
4. Ma, G.S.; Mi, J.; Ma, J. *Report on childhood obesity in China*; 2017.
5. Ng, M.; Fleming, T.; Robinson, M.; Thomson, B.; Graetz, N.; Margono, C.; Mullany, E.C.; Biryukov, S.; Abafati, C.; Abera, S.F., et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* **2014**, *384*, 766-781, doi:10.1016/S0140-6736(14)60460-8.
6. Cote, A.T.; Harris, K.C.; Panagiotopoulos, C.; Sandor, G.G.; Devlin, A.M. Childhood obesity and cardiovascular dysfunction. *J Am Coll Cardiol* **2013**, *62*, 1309-1319, doi:10.1016/j.jacc.2013.07.042.

7. Park, M.H.; Falconer, C.; Viner, R.M.; Kinra, S. The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review. *Obes Rev* **2012**, *13*, 985-1000, doi:10.1111/j.1467-789X.2012.01015.x.
8. Pavlicek, V. Obesity in childhood as a risk factor for type-2-diabetes. *Diabetologe* **2018**, *14*, 342-343, doi:10.1007/s11428-018-0354-7.
9. da Rosa, G.J.; Schivinski, C.I. Assessment of respiratory muscle strength in children according to the classification of body mass index. *Rev Paul Pediatr* **2014**, *32*, 250-255.
10. Yan, B.; Pang, S.J. Research progress on harm of childhood obesity. *Journal of Xinxiang Medical University* **2018**, *35*, 840-842.
11. Klinedinst, B.S.; Pappas, C.; Le, S.; Yu, S.; Wang, Q.; Wang, L.; Allenspach-Jorn, K.; Mochel, J.P.; Willette, A.A. Aging-related changes in fluid intelligence, muscle and adipose mass, and sex-specific immunologic mediation: A longitudinal UK Biobank study. *Brain Behav Immun* **2019**, *82*, 396-405, doi:10.1016/j.bbi.2019.09.008.
12. Zhang, C.; Yue, C.; Herrmann, A.; Song, J.; Egelston, C.; Wang, T.; Zhang, Z.; Li, W.; Lee, H.; Aftabizadeh, M., et al. STAT3 activation-induced fatty acid oxidation in CD8+ T effector cells Is critical for obesity-promoted breast tumor growth. *Cell metabolism* **2020**, *31*, 148-161.e145, doi:10.1016/j.cmet.2019.10.013.
13. Jia, P.; Xue, H.; Zhang, J.; Wang, Y. Time trend and demographic and geographic disparities in childhood obesity prevalence in China-evidence from twenty years of longitudinal data. *Int J Environ Res Public Health* **2017**, *14*, doi:10.3390/ijerph14040369.
14. Murasko, J.E. Height, BMI, and relative economic standing in children from developing countries. *Am J Hum Biol* **2017**, *29*, doi:10.1002/ajhb.22958.

15. Wu, X.L.; Zhao, W.; Li, J.J.; Wang, L.; Yang, M.; Li, L.B. Study on influencing factors of simple obesity of preschool children in Beijing. *Chin J Child Heal Care* **2015**, *23*, 340-343.
16. Lin, L. Leisure-time physical activity, objective urban neighborhood built environment, and overweight and obesity of Chinese school-age children. *Journal of Transport & Health* **2018**, *10*, 322-333, doi:10.1016/j.jth.2018.05.001.
17. Wilkie, H.J.; Standage, M.; Gillison, F.B.; Cumming, S.P.; Katzmarzyk, P.T. Correlates of intensity-specific physical activity in children aged 9-11 years: a multilevel analysis of UK data from the International Study of Childhood Obesity, Lifestyle and the Environment. *BMJ Open* **2018**, *8*, e018373, doi:10.1136/bmjopen-2017-018373.
18. de Bont, J.; Casas, M.; Barrera-Gomez, J.; Cirach, M.; Rivas, I.; Valvi, D.; Alvarez, M.; Dadvand, P.; Sunyer, J.; Vrijheid, M. Ambient air pollution and overweight and obesity in school-aged children in Barcelona, Spain. *Environ Int* **2019**, *125*, 58-64, doi:10.1016/j.envint.2019.01.048.
19. Zhang, Y.X. Changes in the nutritional status of children and adolescents in Shandong, China. *Public Health Nutr* **2016**, *19*, 2708-2711, doi:10.1017/S1368980016000963.
20. Mekonnen, T.; Tariku, A.; Abebe, S.M. Overweight/obesity among school aged children in Bahir Dar City: cross sectional study. *Ital J Pediatr* **2018**, *44*, 17, doi:10.1186/s13052-018-0452-6.
21. Wang, H.; Xue, H.; Du, S.; Zhang, J.; Wang, Y.; Zhang, B. Time trends and factors in body mass index and obesity among children in China: 1997-2011. *Int J Obes (Lond)* **2017**, *41*, 964-970, doi:10.1038/ijo.2017.53.
22. Sagbo, H.; Ekouevi, D.K.; Ranjandriarison, D.T.; Niangoran, S.; Bakai, T.A.; Afanvi, A.; Dieudonne, S.; Kassankogno, Y.; Vanhems, P.; Khanafer, N. Prevalence and factors associated with overweight and

- obesity among children from primary schools in urban areas of Lome, Togo. *Public Health Nutr* **2018**, *21*, 1048-1056, doi:10.1017/S1368980017003664.
23. Statistics, S.P.B.o. *Shandong Statistical Yearbook-2018*; China Statistics Press: 2018.
24. National Health Commission of the People's Republic of China , M.o.E.o.t.P.s.R.o.C. Measures for the administration of health examination of primary and middle school students. Availabe online: http://www.gov.cn/gongbao/content/2008/content_1175830.htm (accessed on 21 March).
25. Department, S.P.E. Measures for the implementation of health examination management for primary and middle school students in Shandong province. Availabe online: http://www.sdedu.gov.cn/sdjy/_zcwj/472300/index.html (accessed on 21 March).
26. U.S. Department of Health and Human Services, C.f.D.C.a.P. CDC Growth Charts: United States. Availabe online: <http://www.cdc.gov/growthcharts/background.htm> (accessed on 15 March).
27. Cole, T.J.; Lobstein, T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes* **2012**, *7*, 284-294, doi:10.1111/j.2047-6310.2012.00064.x.
28. Goryakin, Y.; Suhrcke, M. Economic development, urbanization, technological change and overweight: what do we learn from 244 Demographic and Health Surveys? *Econ Hum Biol* **2014**, *14*, 109-127, doi:10.1016/j.ehb.2013.11.003.
29. Ebrahimi, N.; Taheri, F.; Moodi, M.; Zardast, M. The effect of educational intervention on body mass index and thyroid function tests in children and adolescents with obesity and overweight. *International Journal of Pediatrics-Mashhad* **2018**, *6*, 8101-8110, doi:10.22038/ijp.2017.27747.2403.

30. Chen, J.; Yang, S.T.; Li, H.W.; Zhang, B.; Lv, J.R. Research on geographical environment unit division based on the method of natural breaks (Jenks). *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* **2013**, XL-4/W3, 47-50, doi:10.5194/isprsarchives-XL-4-W3-47-2013.
31. ESRI. How Spatial Autocorrelation (Global Moran's I) works. Available online: <http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-statistics-toolbox/h-how-spatial-autocorrelation-moran-s-i-spatial-st.htm> (accessed on 3.21).
32. ESRI. How Hot Spot Analysis (Getis-Ord Gi*) works. Available online: <http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-statistics-toolbox/h-how-hot-spot-analysis-getis-ord-gi-spatial-stati.htm> (accessed on 3.20).
33. Khashayar, P.; Kasaeian, A.; Heshmat, R.; Motlagh, M.E.; Mahdavi Gorabi, A.; Noroozi, M.; Qorbani, M.; Kelishadi, R. Childhood overweight and obesity and associated factors in Iranian children and adolescents: A multilevel analysis; the CASPIAN-IV study. *Front Pediatr* **2018**, *6*, 393, doi:10.3389/fped.2018.00393.
34. Collaboration, N.C.D.R.F. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet* **2017**, *390*, 2627-2642, doi:10.1016/S0140-6736(17)32129-3.
35. Zhang, Y.X.; Wang, S.R.; Chen, M.; Cheng, Y. Recent trends in body mass index and waist circumference among children and adolescents in Shandong China. *J Trop Pediatr* **2017**, *63*, 461-467, doi:10.1093/tropej/fmx013.
36. Kjellberg, J.; Tange Larsen, A.; Ibsen, R.; Hojgaard, B. The socioeconomic burden of obesity. *Obes Facts* **2017**, *10*, 493-502, doi:10.1159/000480404.

37. Qin, W.; Wang, L.; Xu, L.; Sun, L.; Li, J.; Zhang, J.; Shao, H. An exploratory spatial analysis of overweight and obesity among children and adolescents in Shandong, China. *BMJ open* **2019**, *9*, e028152-e028152, doi:10.1136/bmjopen-2018-028152.
38. Zhou, Q.; Wang, P.X.; Zhou, Z.H.; Li, F.J.; Wang, J.J. The prevalence of obesity and its influencing factors among teenagers aged 7 –17 years in Foshan region. *Practical Preventive Medicine* **2014**, *21*, 1394-1396.
39. Qin, Y.L.; Xiong, F.; Zhao, Y.; Zhu, M.; Luo, Y.H.; Wang, F.L.; Zeng, Y.; Wu, L.P.; Ma, Q.X.; Yang, B., et al. Analysis on childhood obesity incidences between urban and rural in Chongqing and its related factors. *Journal of Chongqing Medical University* **2013**, *38*, 827-832, doi:10.11699/cyxb20130803.
40. Zhang, J.; Wang, H.; Wang, Y.; Xue, H.; Wang, Z.; Du, W.; Su, C.; Zhang, J.; Jiang, H.; Zhai, F., et al. Dietary patterns and their associations with childhood obesity in China. *Br J Nutr* **2015**, *113*, 1978-1984, doi:10.1017/S0007114515001154.
41. Dinsa, G.D.; Goryakin, Y.; Fumagalli, E.; Suhrcke, M. Obesity and socioeconomic status in developing countries: a systematic review. *Obes Rev* **2012**, *13*, 1067-1079, doi:10.1111/j.1467-789X.2012.01017.x.
42. Paisi, M.; Kay, E.; Kaimi, I.; Witton, R.; Nelder, R.; Christophi, C.; Lapthorne, D. Obesity and dental caries in young children in plymouth, United Kingdom: A spatial analysis. *Community Dent Health* **2018**, *35*, 58-64, doi:10.1922/CDH_4214Paisi07.
43. Tomata, Y.; Tanno, K.; Zhang, S.; Sakai, M.; Kobayashi, K.; Kurasawa, N.; Tanaka, M.; Kamada, Y.; Tsuji, I.; Hiramoto, F. Subjective household economic status and obesity in toddlers: A cross-sectional study of daycare centers in Japan. *J Epidemiol* **2019**, *29*, 33-37, doi:10.2188/jea.JE20170081.
44. Guo, C.; Wang, H.; Feng, G.; Li, J.; Su, C.; Zhang, J.; Wang, Z.; Du, W.; Zhang, B. Spatiotemporal predictions of obesity prevalence in Chinese children and adolescents: based on analyses of obesogenic

- environmental variability and Bayesian model. *Int J Obes (Lond)* **2019**, *43*, 1380-1390, doi:10.1038/s41366-018-0301-0.
45. Oliveira, J.S.; Barufaldi, L.A.; Abreu Gde, A.; Leal, V.S.; Brunken, G.S.; Vasconcelos, S.M.; dos Santos, M.M.; Bloch, K.V. ERICA: use of screens and consumption of meals and snacks by Brazilian adolescents. *Rev Saude Publica* **2016**, *50 Suppl 1*, 7s, doi:10.1590/S01518-8787.2016050006680.
46. Vanderwall, C.; Randall Clark, R.; Eickhoff, J.; Carrel, A.L. BMI is a poor predictor of adiposity in young overweight and obese children. *BMC Pediatr* **2017**, *17*, 135, doi:10.1186/s12887-017-0891-z.
47. Li, H.J.; Yang, L.; Zhang, N. Accuracy of bodymass index as a screeningstandard for obesity. *China Preventive Medicine* **2014**, *15*, 571-575.
48. Kral, T.V.E.; Moore, R.H.; Chittams, J.; Jones, E.; O'Malley, L.; Fisher, J.O. Identifying behavioral phenotypes for childhood obesity. *Appetite* **2018**, *127*, 87-96, doi:10.1016/j.appet.2018.04.021.
49. Alberti, K.G.M.M.; Zimmet, P.; Shaw, J. The metabolic syndrome - a new worldwide definition. *Lancet* **2005**, *366*, 1059-1062, doi:Doi 10.1016/S0140-6736(05)67402-8.
50. Durnin, J.V.G.A.; Womersley, J. Body fat assessed from total-body density and its estimation from skinfold thickness - measurements on 481 men and women aged from 16 to 72 years. *Brit J Nutr* **1974**, *32*, 77-97, doi:Doi 10.1079/Bjn19740060.

Figure 1 Spatial distribution of total schoolchildren with overweight aged 6-18 in Shandong province in 2017.

Figure 2 Spatial distribution of total schoolchildren with obesity aged 6-18 in Shandong province in 2017.

Figure 3 Spatial distribution of overweight in boys aged 6-18 in Shandong province in 2017.

Figure 4 Spatial distribution of overweight in girls aged 6-18 in Shandong province in 2017.

Figure 5 Spatial distribution of obesity in boys aged 6-18 in Shandong province in 2017.

Figure 6 Spatial distribution of obesity in girls aged 6-18 in Shandong province in 2017.

Figure 7 Spatial aggregation of overweight in schoolchildren aged 6-18 in Shandong province in 2017

Figure 8 Spatial aggregation of overweight in boys aged 6-18 in Shandong province in 2017

Figure 9 Spatial aggregation of overweight in girls aged 6-18 in Shandong province in 2017

Figure 10 Spatial aggregation of obesity in schoolchildren aged 6-18 in Shandong province in 2017

Figure 11 Spatial aggregation of obesity in boys aged 6-18 in Shandong province in 2017

Figure 12 Spatial aggregation of obesity in girls aged 6-18 in Shandong province in 2017

Figures

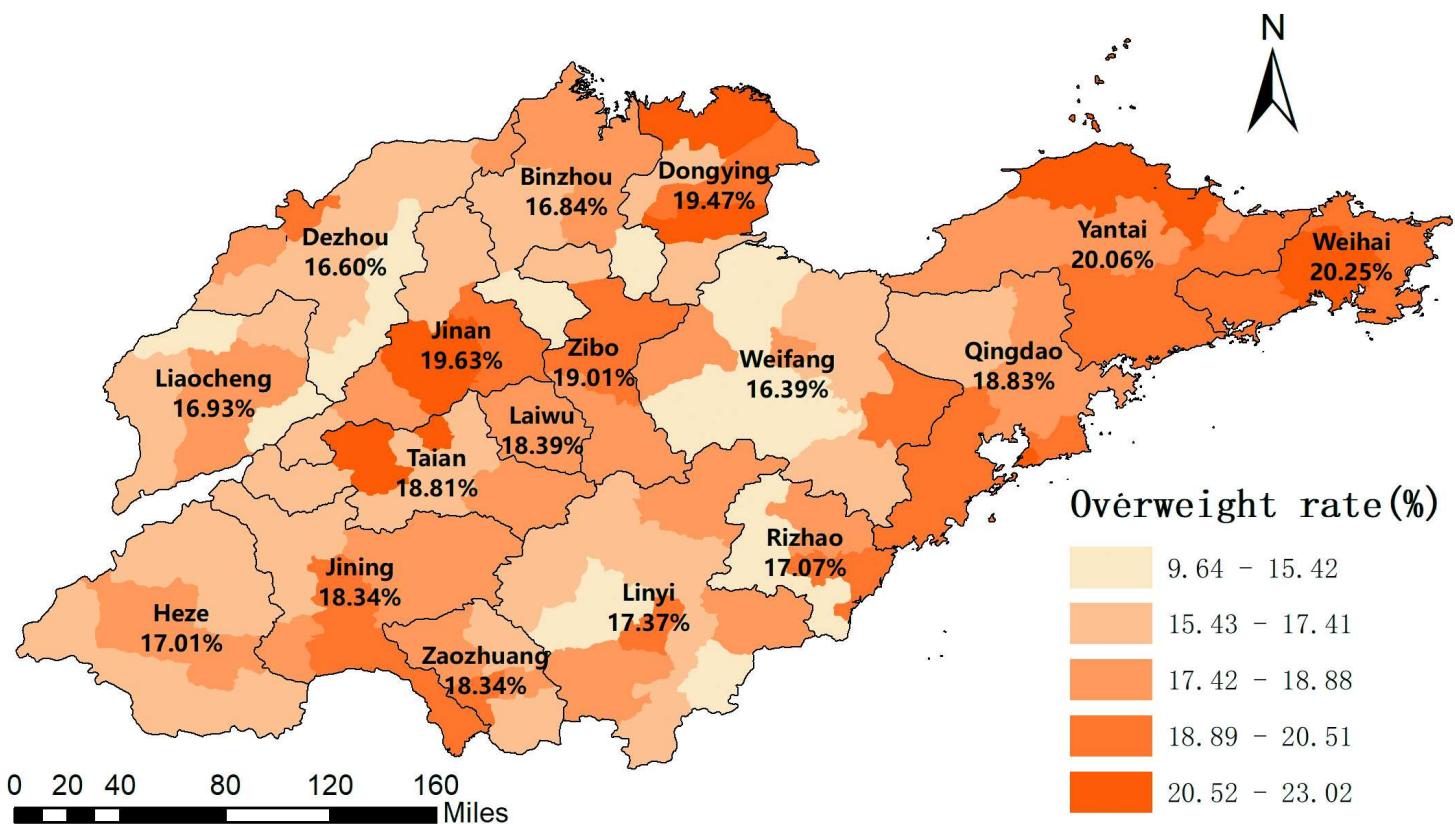


Figure 1

Spatial distribution of total schoolchildren with overweight aged 6-18 in Shandong province in 2017.
Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

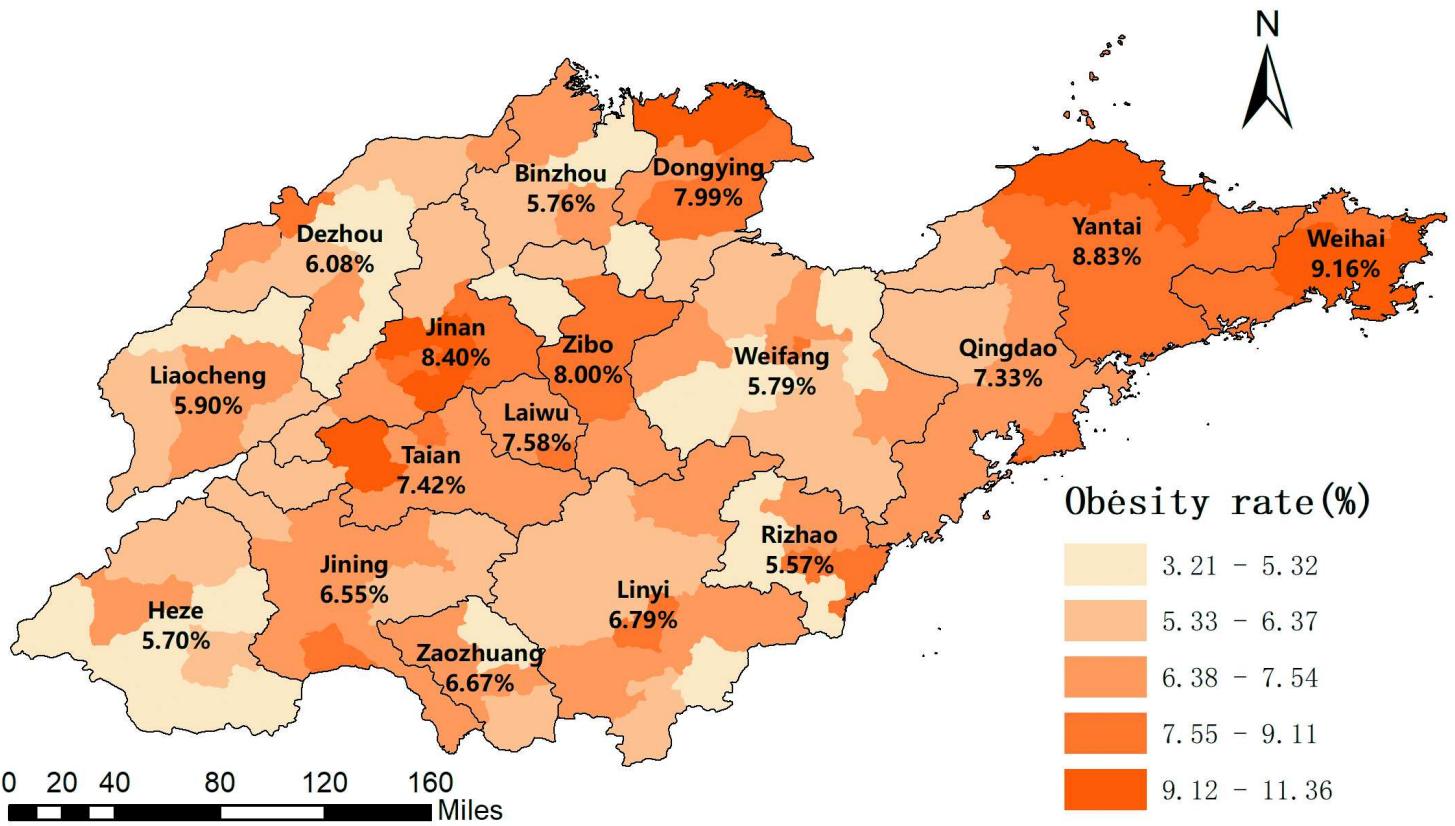


Figure 2

Spatial distribution of total schoolchildren with obesity aged 6-18 in Shandong province in 2017. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

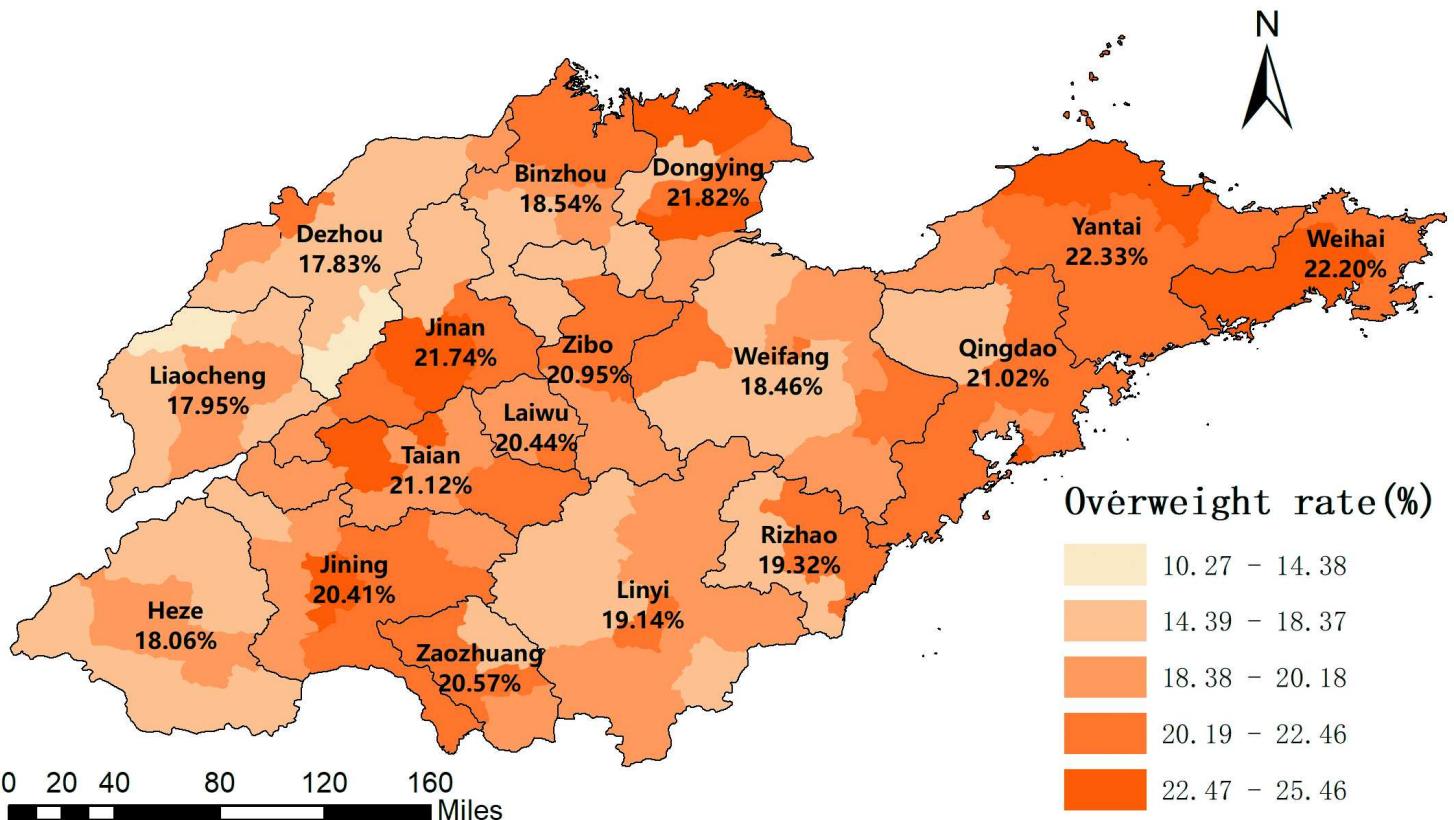


Figure 3

Spatial distribution of overweight in boys aged 6-18 in Shandong province in 2017. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

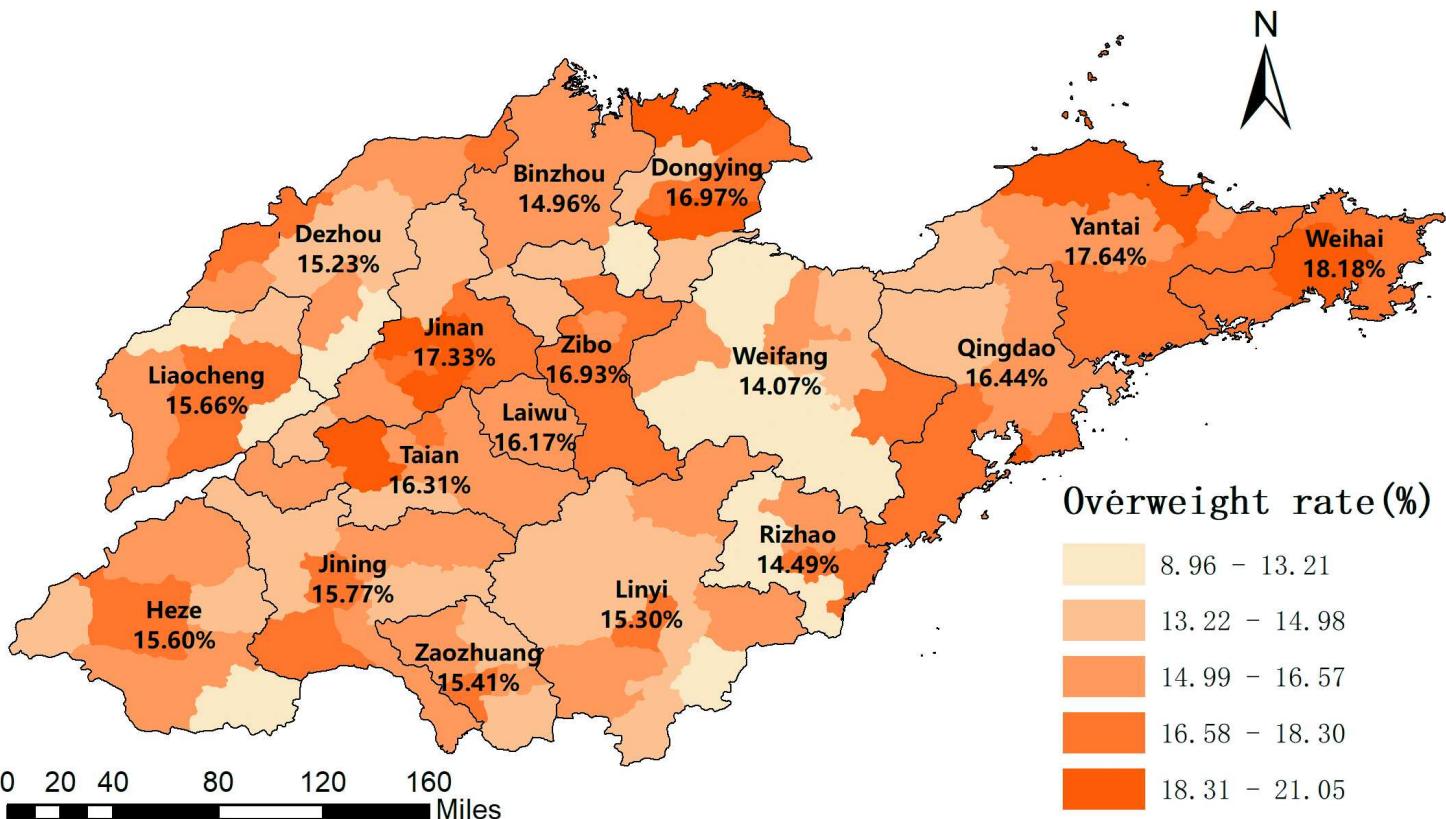


Figure 4

Spatial distribution of overweight in girls aged 6-18 in Shandong province in 2017. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

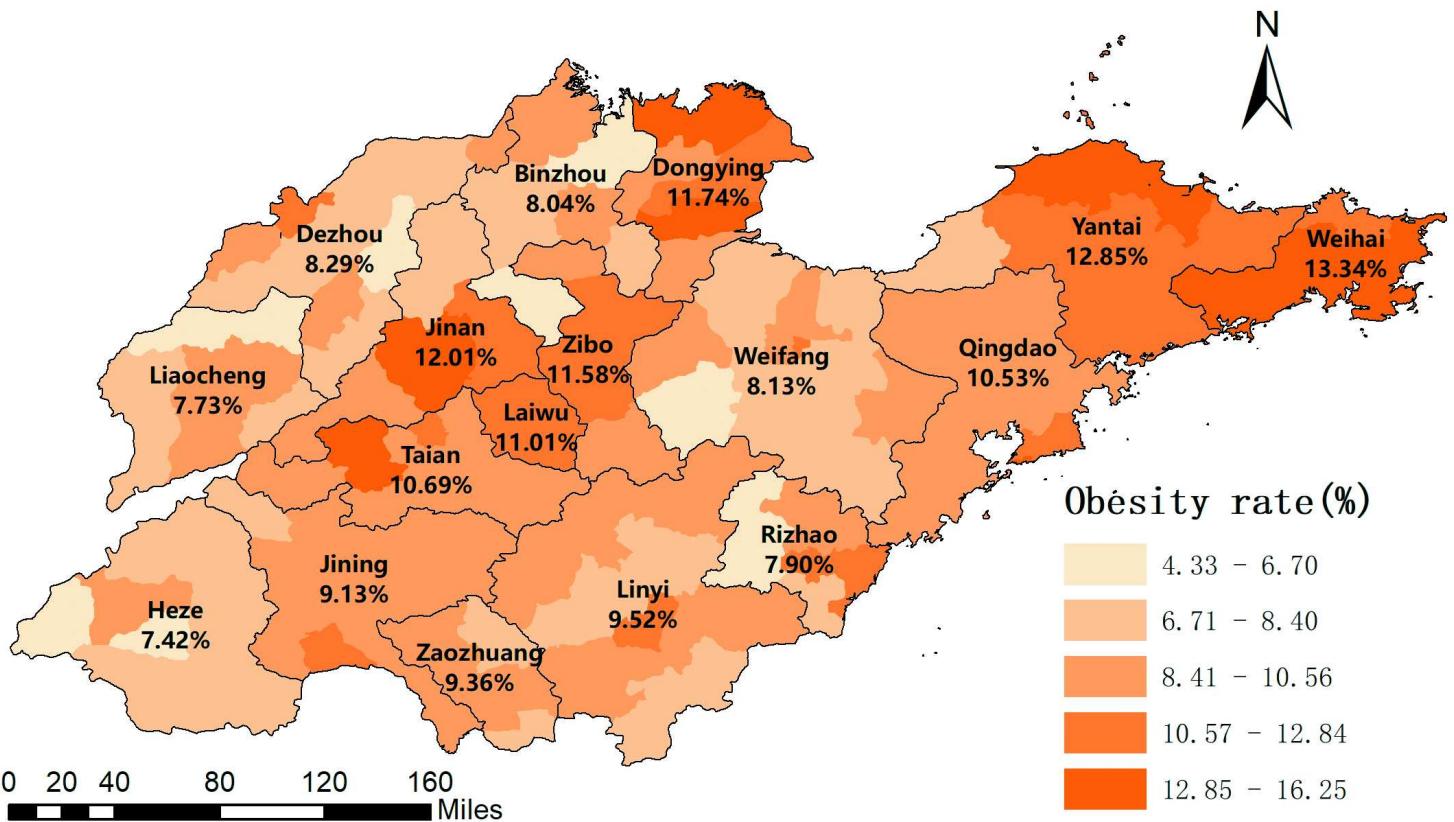


Figure 5

Spatial distribution of obesity in boys aged 6-18 in Shandong province in 2017. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

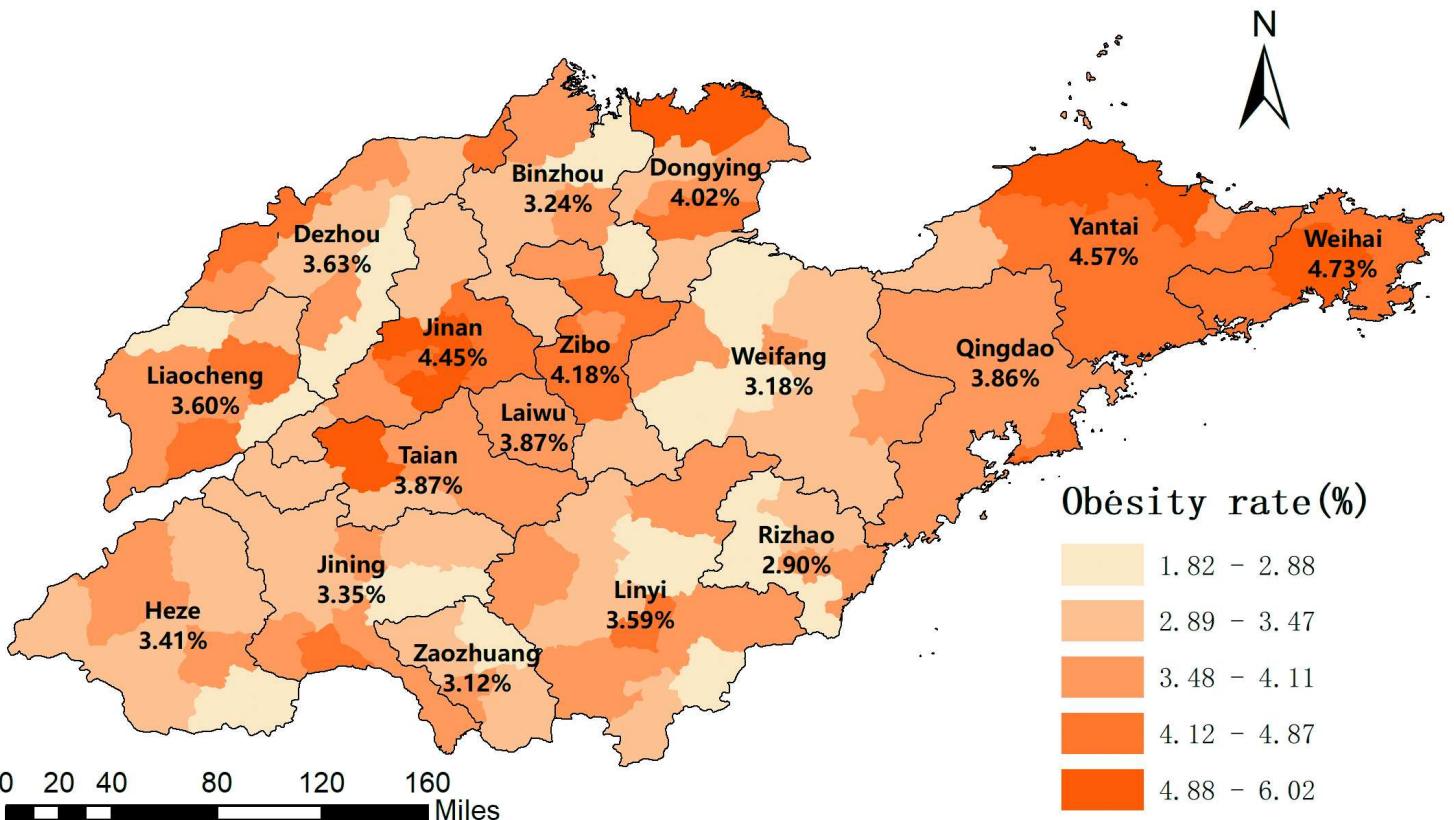


Figure 6

Spatial distribution of obesity in girls aged 6-18 in Shandong province in 2017. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

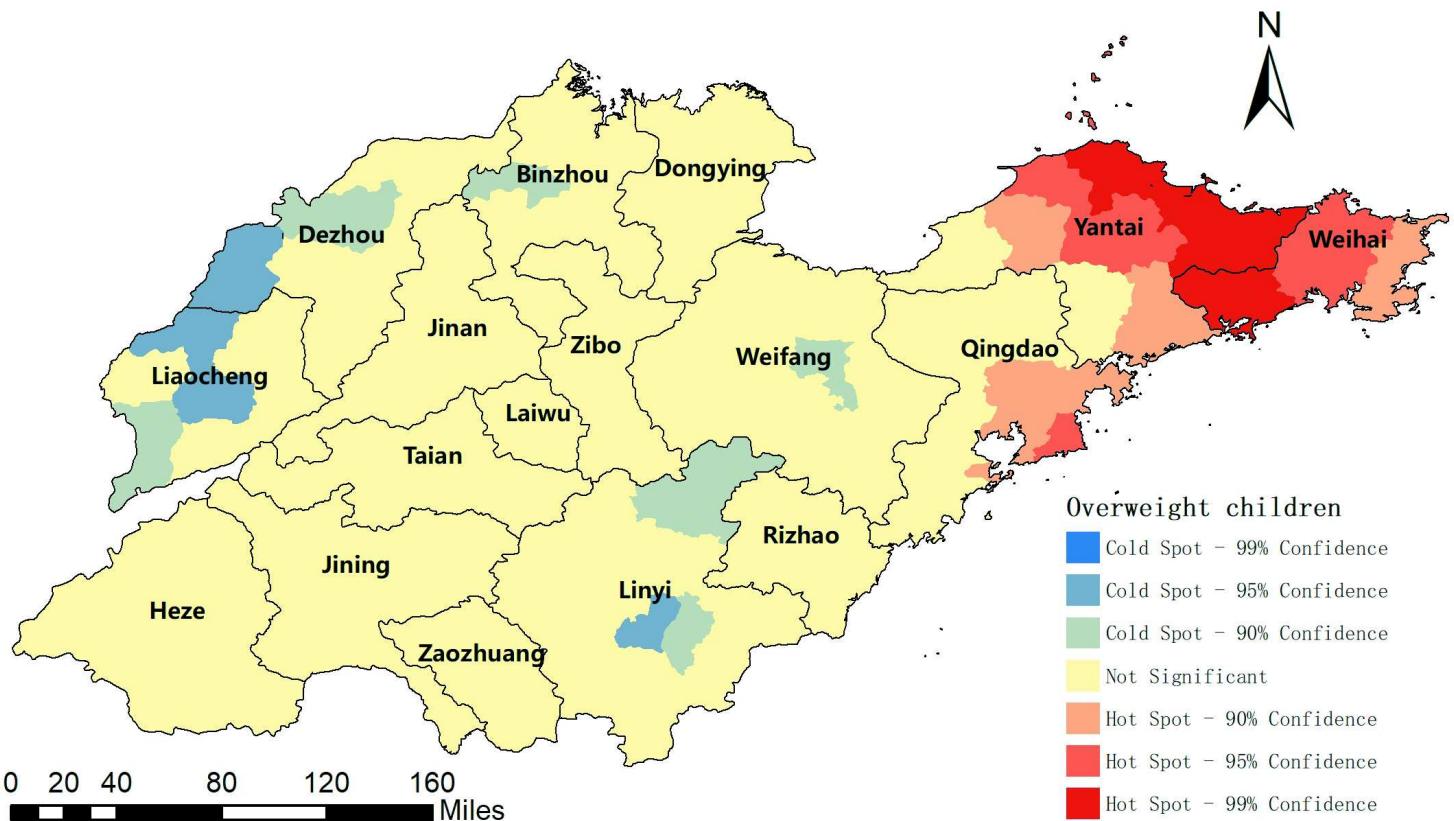


Figure 7

Spatial aggregation of overweight in schoolchildren aged 6-18 in Shandong province in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

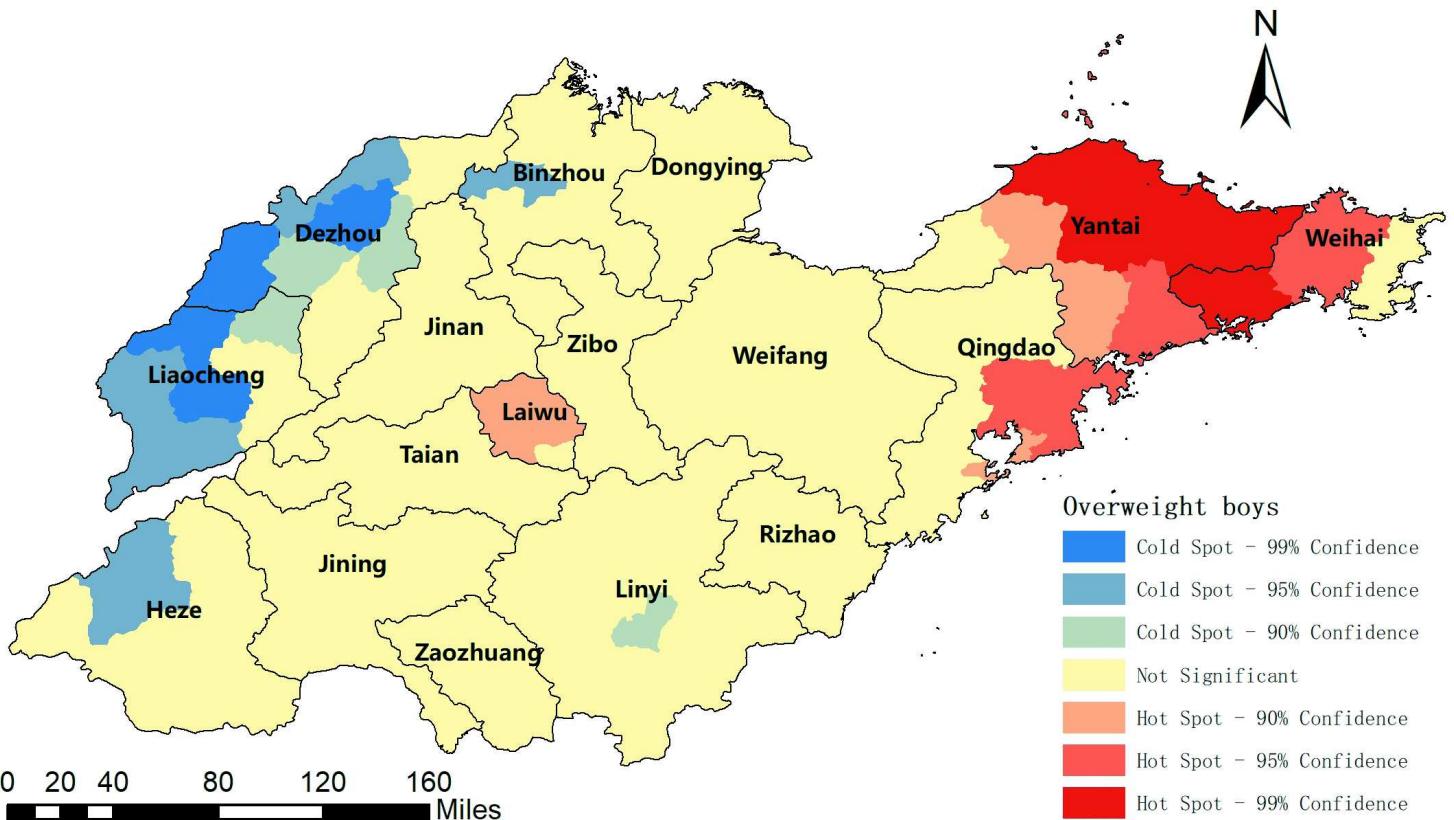


Figure 8

Spatial aggregation of overweight in boys aged 6-18 in Shandong province in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

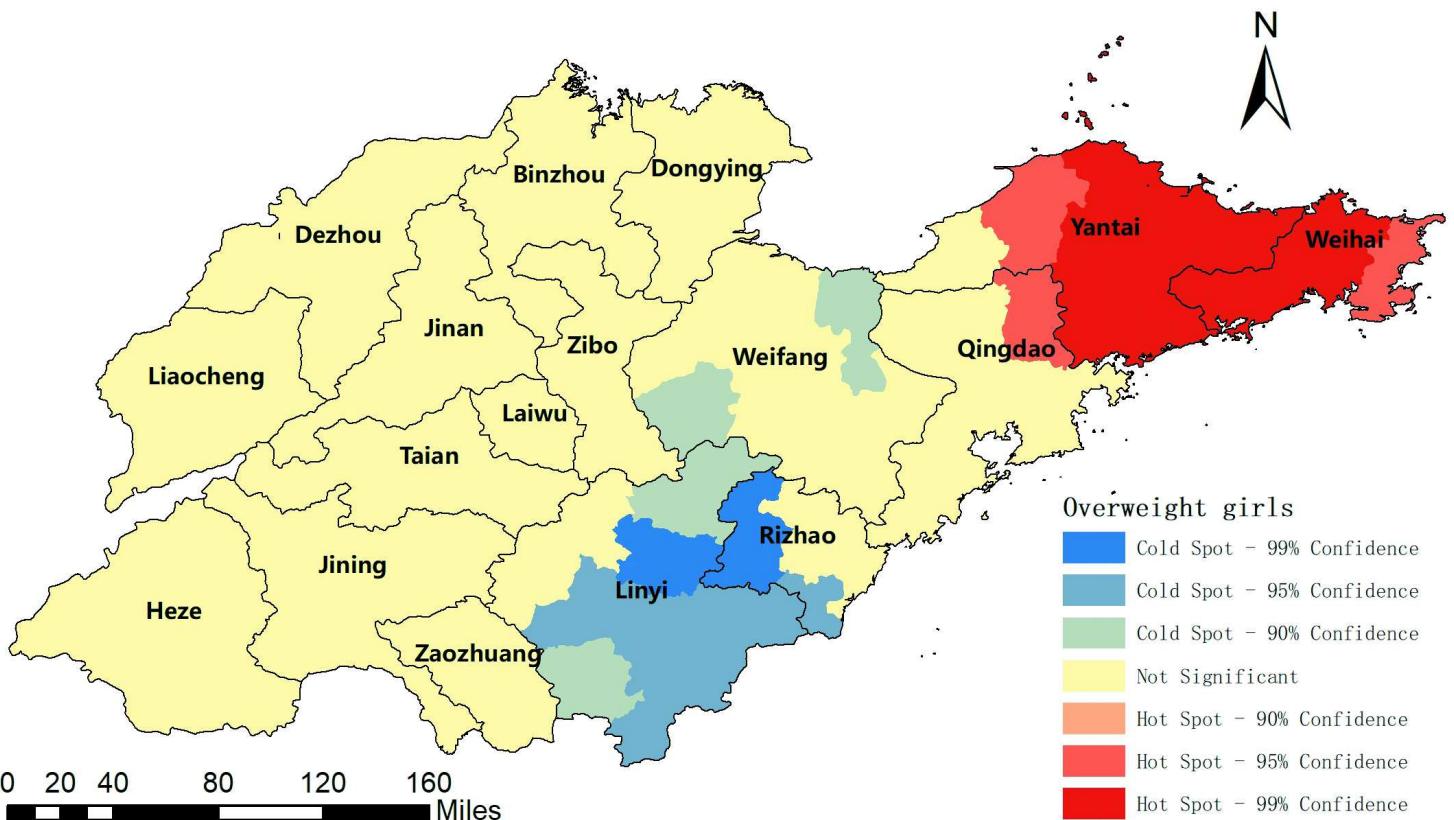


Figure 9

Spatial aggregation of overweight in girls aged 6-18 in Shandong province in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

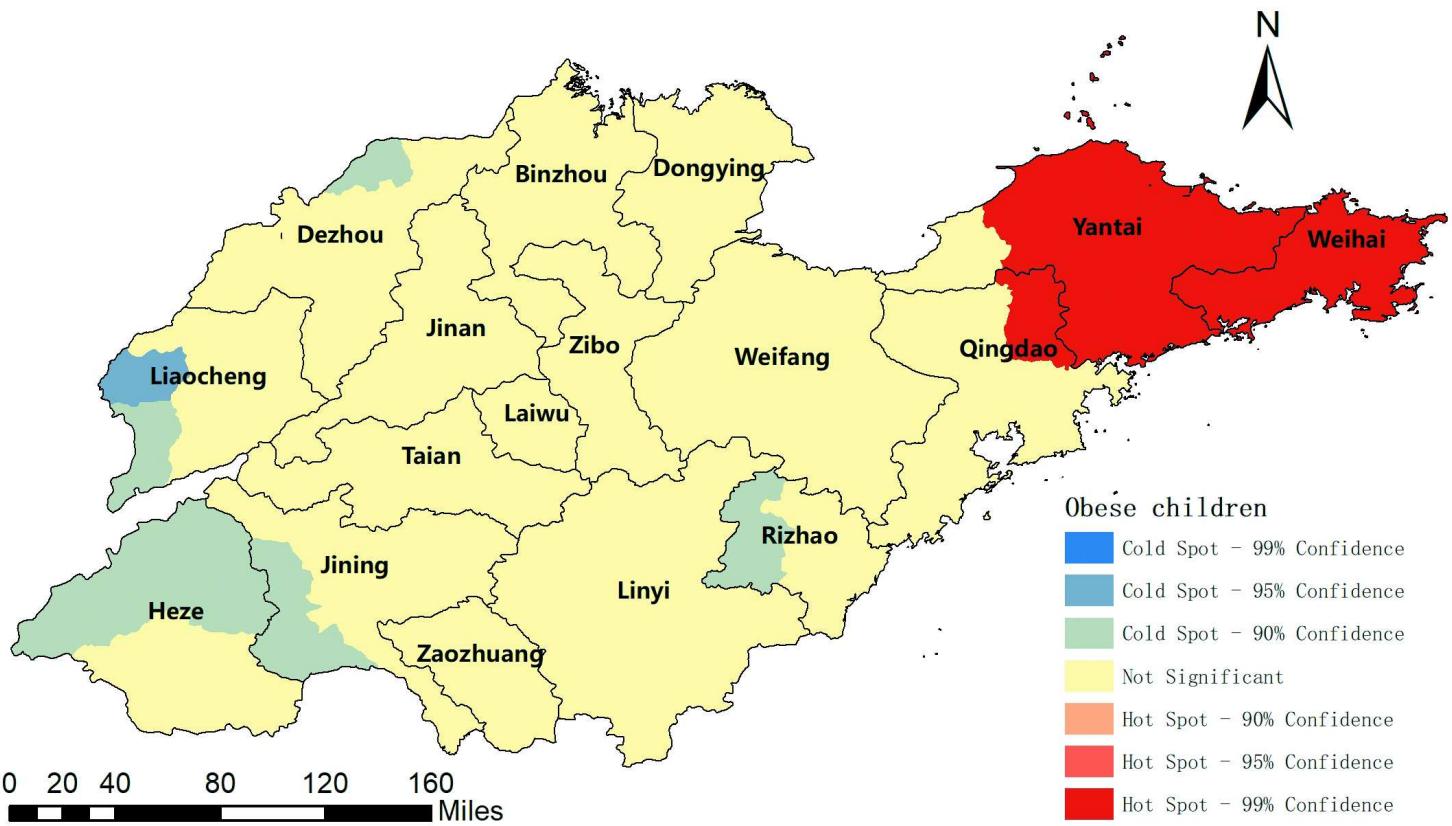


Figure 10

Spatial aggregation of obesity in schoolchildren aged 6-18 in Shandong province in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

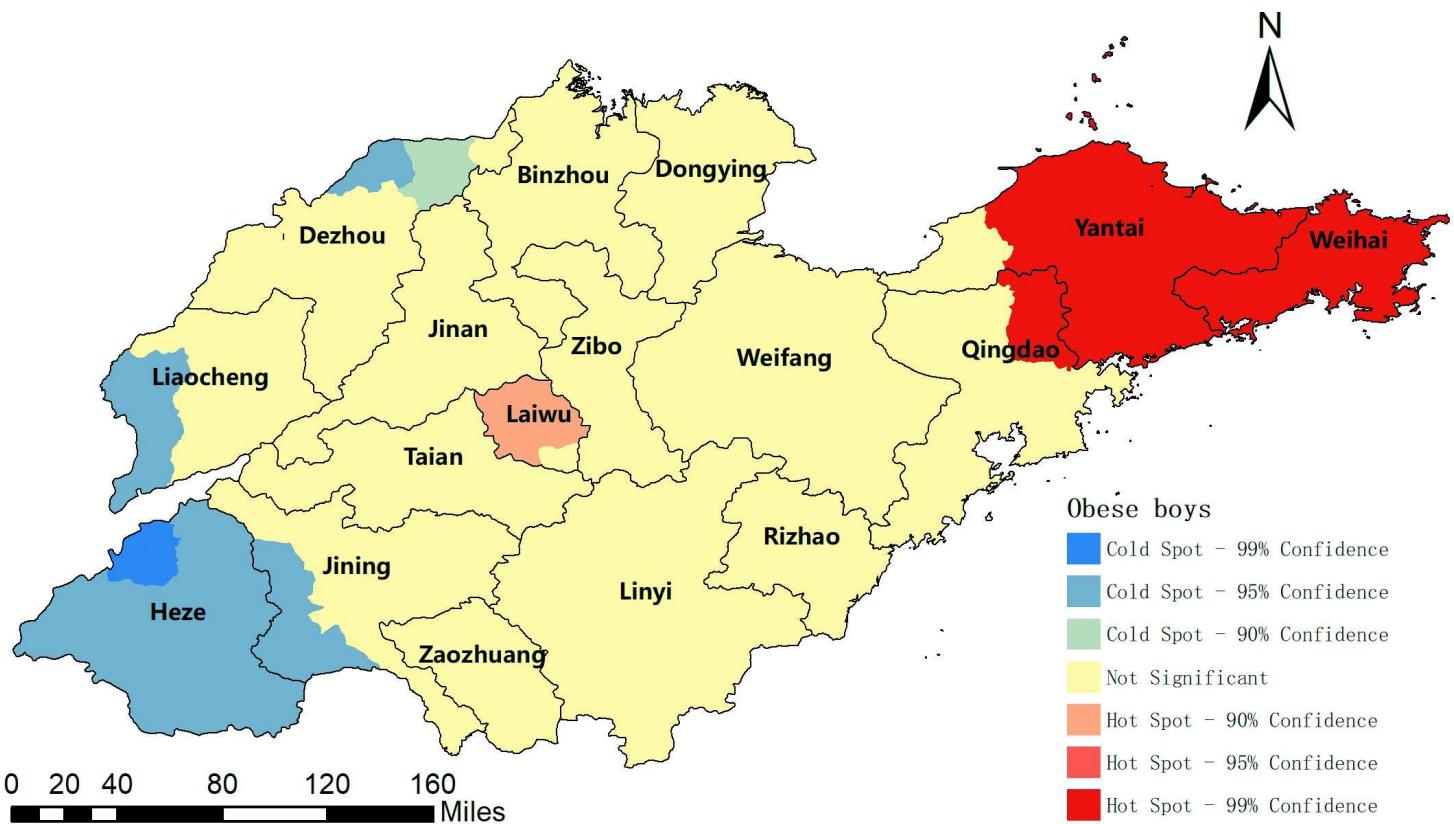


Figure 11

Spatial aggregation of obesity in boys aged 6-18 in Shandong province in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

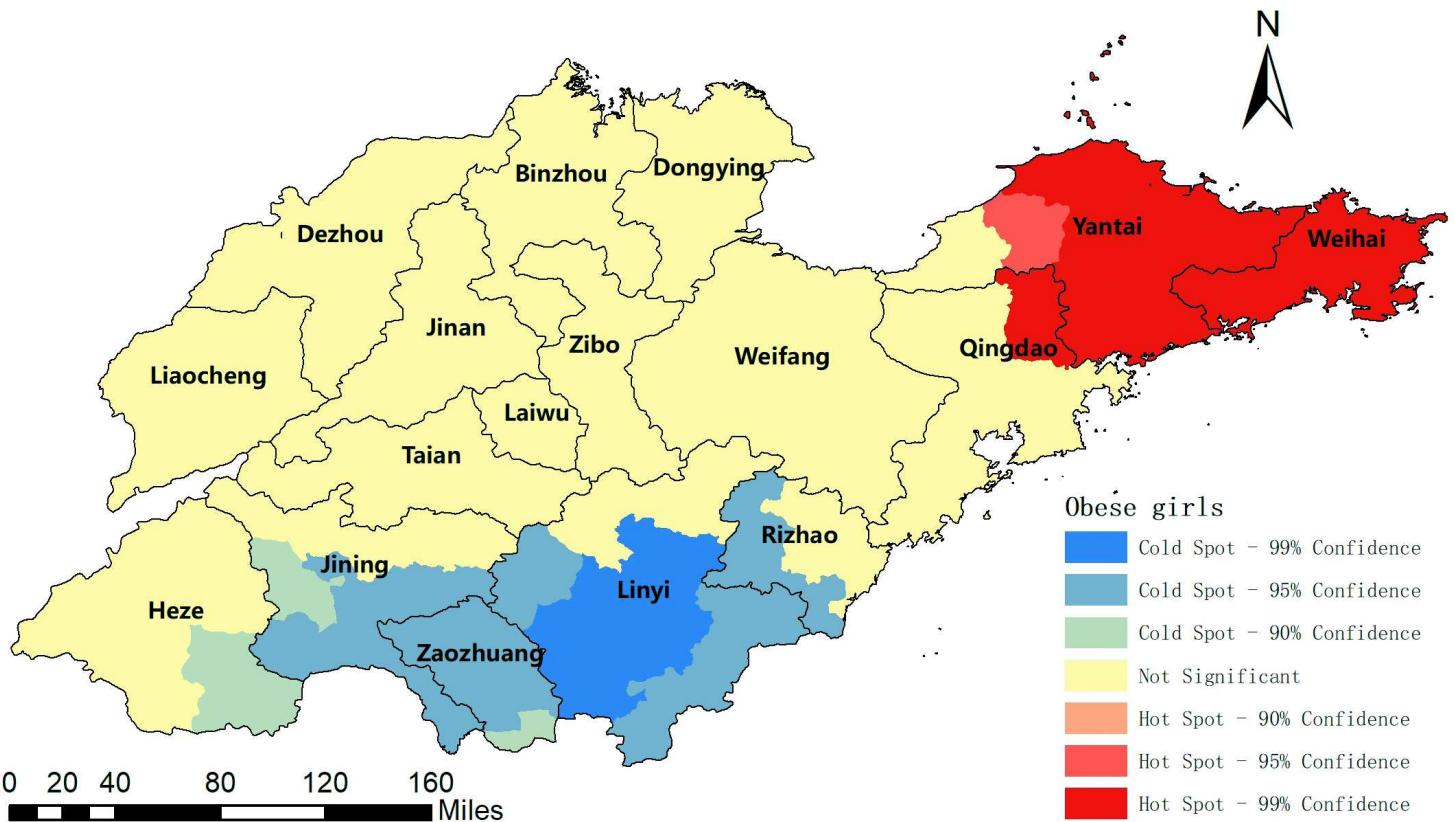


Figure 12

Spatial aggregation of obesity in girls aged 6-18 in Shandong province in 2017 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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